

THE EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION

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Two earlier reports¹ from this laboratory seemed sufficiently to establish the point that a film of Bordeaux mixture increases the rate of transpiration of excised leaves of the castor bean, and likewise of potted tomato and potato plants. It was further indicated that other surface films, and to a slight extent dusts, may produce a similar, though on the whole lesser, accelerating effect. Nevertheless, it was felt that this work left incompletely answered questions relating both to the immediate and final effects of the spray, as well as to the relation of the acceleration found to night and day conditions, or to changes of environmental conditions in general. Again, it seemed eminently desirable to construct and employ in this work a rotating table, or transpirotaplane, by means of which it might be hoped to eliminate such errors as might arise from differing transpiration rates induced through the position of the plants in the different intervals, whether the plants observed were in the greenhouse or in the open. In the earlier experiments it had not been possible to take sufficient cognizance of these points, but immediately upon the presentation of the reports referred to above, further experiments were begun leading in the directions indicated. A variety of considerations prevented a prompt conclusion of this work. Meanwhile, there has appeared a paper by Martin² affording interesting and definite

¹ Duggar, B. M., and Cooley, J. S. The effect of surface films and dusts on the rate of transpiration. *Ann. Mo. Bot. Gard.* 1 : 1-22. *pl. 1.* 1914; The effects of surface films on the rate of transpiration: experiments with potted potatoes. *Ibid.* 351-356. *pl. 18.* 1914.

² Martin, W. H. Influence of Bordeaux mixture on the rates of transpiration from abscised leaves and from potted plants. *Jour. Agr. Res.* 7 : 529-548. 1916.

confirmation of the previous work, at the same time extending the findings of Duggar and Cooley regarding the accelerating effect of Bordeaux mixture and other surface films on the rate of transpiration of abscised leaves and potted plants. This work of Martin, conducted at the New Jersey Experiment Station, has been followed by a paper from Shive and Martin¹ on the effect of similar films upon the transpiring power of leaves, employing the method of standardized cobalt chloride paper as perfected through the work of Livingston and Shreve.² The method referred to has proved applicable to the investigation of problems of this nature, and affords further decisive evidence of the increased transpiring power of leaves sprayed with Bordeaux. Lutman,³ in his careful study of Bordeaux mixture, has considered transpiration only in a subsidiary manner. He reviews the earlier work of the German observers, which, however, is based on rather inadequate experimentation, and seemed rather inclined to assume that increased transpiration might not be expected; yet his own experiments, so far as they go, indicate in general an increase in transpiration due to the Bordeaux film.

METHODS

In undertaking the present study it was decided to construct a rotating table, for the reasons given above, especially in an effort to eliminate the often rather serious error in transpiration studies, due to differences of exposure of the individual plants involved in the experiment. A rotating table was accordingly devised similar in principle to Livingston's⁴ table for standardizing porous cup atmometers; in addition, however, to the revolution of the several plants about

¹ Shive, J. W., and Martin, W. H. The effect of surface films of Bordeaux mixture on the foliar transpiring power in tomato plants. *Plant World* 20 : 67-86. f. 1. 1917.

² Livingston, B. E., and Shreve, E. B. Improvements in the method for determining the transpiring power of plant surfaces by hygrometric paper. *Ibid.* 19 : 287-309. 1916.

³ Lutman, B. F. Some studies on Bordeaux mixture. *Vt. Agr. Exp. Sta., Bul.* 196:1-80. *pl.* 1-4. *f.* 1-11. 1916.

⁴ Livingston, B. E. A rotating table for standardizing porous cup atmometers. *Plant World* 15 : 157-162. f. 1-2. 1912.

the central axis, each plant was made to turn upon the axis of its own platform.

The construction of the table was as follows:

A heavy cast-iron base, 5 inches in diameter and $3\frac{1}{2}$ inches high, with a footing 12 inches in diameter and $1\frac{1}{2}$ inches thick, supported a polished steel shaft of 1-inch diameter, 4 feet long. Four inches of this shaft were sunk into the top of the base, which had a small shoulder. On this shoulder rested a collar or ring enclosing a set of ball bearings which was slipped over the shaft, these carrying the greater part of the weight of the revolving system.

The 8 arms carrying the plant platforms consisted of $1\times 1\frac{1}{2}$ -inch channel irons, 4 feet long, arranged radially and bolted each with 2 bolts to a central plate 10 inches in diameter. This central plate was screwed to a short collar or outer shaft of iron tubing of $\frac{3}{16}$ -inch thickness which slipped easily over the supporting steel central shaft without excessive play. On the portion of the collar below the central plate was bolted a sprocket wheel $8\frac{1}{2}$ inches in diameter. The collar extended a little more than 1 inch above the central plate. Above this collar was imposed another short collar which was firmly screwed with set screws to the central steel shaft and did not bear upon any of the parts below; a sprocket wheel 3 inches in diameter was bolted to this second collar and a second ring of ball bearings fitted over the latter. On this ring then rested the second outer shaft, which revolved freely over the main steel axis, and extended a short distance above it.

The plant platforms consisted of discs of seasoned wood $\frac{3}{4}$ inch thick and 7 inches in diameter. To the bottom of each was screwed a brass sprocket wheel $2\frac{1}{2}$ inches in diameter. Each of such sprockets fitted over a cylindrical steel plug $\frac{5}{8}$ inch in diameter, projecting $\frac{7}{8}$ inch above the top of a rectangular cast-iron sleeve which slid along the channel iron. The platform could thus be set at any point along the arm, and was fixed by a set screw in one side of the sleeve.

Guy wires connected by steel eyelets from the upper end of the outer revolving shaft to an eyelet set in each channel

iron arm about 16 inches from the free end, with turnbuckles interposed, took up the strain on the arms resulting from heavy plants on the platforms.

One of the platforms, in addition to the brass sprocket below, had a second sprocket 4 inches in diameter, screwed to the latter. This second sprocket was connected by a link chain to the sprocket of the collar screwed to the central steel axis. A steel ladder chain running around the outer teeth of each platform sprocket completed the table proper.

The apparatus was then connected up, by means of a reducing gear attached to the shaft of a $\frac{1}{4}$ -horsepower motor and an intermediate series of sprockets and chains for further reduction of speed, with the large sprocket wheel below the central plate of the table. As the whole table turned on its axis, and the small sprocket screwed to the central steel shaft remained stationary, this resulted in a movement of the link chain connecting this shaft sprocket to the second one on one of the plant platforms; in consequence, this platform turned slowly on its axis, and by means of the ring of the ladder chain transmitted the revolution to the other platforms.

The table as a whole revolved about once every 45 seconds and each plant platform about once every minute. Wherever necessary, the sag of the chains was taken up by supporting them with fiber rollers.

Without exception the experiments were carried out in the greenhouse, and the potted plants used had in all instances been grown under approximately similar conditions and then well accustomed to the environment of the experimental section of the greenhouse. Before being used in the experiments all exposed portions of every pot were coated with paraffin or wax seal. A thistle tube for watering and a bent tube for the release of air pressure were inserted into the soil, and the pot was sufficiently watered before the soil was likewise covered with the seal. When placed upon the platform of the rotating table each pot rested upon a saucer. The use of the rotating table made it somewhat inconvenient to employ any type of auto-irrigator, or constant moisture device, though

very careful attention was given to watering. This was done at intervals sufficiently frequent and in such quantity as to maintain a fairly constant water relation. In the case of all potted plants, where the load was considerable, weighings were made to within 1 gram on a Troemner balance. Moreover, in carrying out the weighings the observer used the same sequence, beginning always with plant No. 1 and concluding the 8 weighings in 6–8 minutes. Therefore, the observation intervals varied by a maximum of less than 2 minutes for the plants in any series, so that with intervals generally greater than 1 hour such variations are entirely negligible.

As in our earlier work, and as followed by subsequent investigators, observations were made on the basis of several to many standardization intervals prior to spraying; that is, the rates of the plants to be sprayed and of those to remain as the control were first determined, furnishing a basis for a ratio between controls and those to be Bordeauxed. Then after the application of the sprays to the plants designated for these—allowing sufficient time for the complete drying of the films—observations were again made on the control and the sprayed plants for a suitable number of intervals.

EXPERIMENTAL

The experimental data are included in a series of tables arranged in a manner as uniform as possible. In the first column at the left of each table is recorded a number by means of which to identify the various time intervals, or “runs”; in the second column the actual period of time covered by the interval is included (likewise ratios computed from the remaining columns), and then follow 8 columns—for the 8 plants involved in each experiment—numbered in order and giving the transpiration quantities for each. The letters accompanying the numbers signify the treatment proposed or given; thus, during any standardization interval K = control, B = Bordeaux, BL = Bordeaux with excess of lime, L = a lime wash, and BC = Bordeaux with excess of the copper salt. Other letters will be explained in connection

with special tables. In order readily to distinguish the quantities in the after-standardization intervals, that is, in the intervals after the application of the spray, the letters are written K', B', BL', etc.

The Bordeaux mixture was prepared as indicated in an earlier report, essentially the standard 4-6-50 formula of pathologists, while the mixture referred to as copper Bordeaux is the 6-4-50 formula, and that called lime Bordeaux is the standard Bordeaux diluted with an equal quantity of lime wash.

TABLE I
(Series A.—Potted potatoes)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1B*	2K†	3B	4K	5B	6K	7B	8K
I	8:20 A.M.—11:25 A.M. 1/9/17	19	20	13	11	13	22	15	8
	K:B = 61:60 = 1:.98	Sunshine							
II	11:25 A.M.—3:25 P.M. 1/9/17	27	30	23	15	19	33	22	15
	K:B = 93:91 = 1:.98	Sunshine							
III	3:25 P.M.—8:28 P.M. 1/9/17	6	4	6	6	3	7	7	5
	K:B = 22:22 = 1:1	Sunshine during early P.M. hours							
IV	8:28 P.M.—9:57 A.M. 1/10/17	16	13	17	10	7	16	18	11
	K:B = 50:58 = 1:1.16	Cloudy during early A.M. hours							
		1B'	2K'	3B'	4K'	5B'	6K'	7B'	8K'
V	4:00 P.M.—8:36 A.M. 1/11/17	49	11	38	15	24	17	52	17
	K':B' = 60:163 = 1:2.71	Sunshine at 4 P.M.							
VI	8:36 A.M.—12:31 P.M. 1/11/17	31	32	28	20	21	36	30	19
	K':B' = 107:110 = 1:1.03	Sunshine							
VII	12:31 P.M.—2:33 P.M. 1/11/17	21	28	17	14	15	24	21	14
	K':B' = 80:74 = 1:.93	Sunshine							

* B = Bordeaux mixture. † K = control.

If, in table I, the total water loss of the intervals before spraying is compared with the total after spraying, the ratio changes from 1.02 to 1.4, a percentage increase of 37 per cent to be attributed to the Bordeaux film. However, in view of the possible effects of environmental conditions, it is of in-

terest to compare some single intervals which are more or less comparable from the standpoint of length of interval and weather conditions. On this basis we may compare interval IV before standardization with interval V immediately after

TABLE II
(Series B.—Potted potatoes)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1K	2B	3K	4B	5K	6BL*	7B	8BL
I	3:27 P.M.—4:59 P.M. 2/12/17	14	8	8	6	10	6	6	9
	K:B:BL = 32:20:15 = 1:63:47								
II	4:59 P.M.—7:07 A.M. 2/13/17	26	15	23	10	15	14	16	27
	K:B:BL = 64:41:41 = 1:64:64								
III	7:07 A.M.—1:10 P.M. 2/13/17	37	23	20	24	18	19	16	23
	K:B:BL = 75:63:42 = 1:84:56								
IV	1:10 P.M.—4:13 P.M. 2/13/17	17	17	15	16	17	11	12	16
	K:B:BL = 49:45:27 = 1:92:55								
V	4:51 P.M.—9:14 A.M. 2/14/17	16	11	17	9	16	10	14	18
	K:B:BL = 49:34:28 = 1:69:57								
VI	9:14 A.M.—1:53 P.M. 2/14/17	43	24	37	33	34	21	26	29
	K:B:BL = 114:83:50 = 1:73:44								
VII	1:53 P.M.—3:10 P.M. 2/14/17	8	4	5	7	4	5	4	5
	K:B:BL = 17:15:10 = 1:88:59								
VIII	3:10 P.M.—6:02 P.M. 2/14/17	8	1	7	5	4	5	3	7
	K:B:BL = 19:9:12 = 1:47:63								
IX	6:02 P.M.—9:35 A.M. 2/15/17	20	14	23	13	17	15	22	23
	K:B:BL = 60:49:38 = 1:82:63								
X	9:35 A.M.—1:21 P.M. 2/15/17	28	39	34	35	31	29	23	30
	K:B:BL = 93:97:59 = 1:1.04:63								
XI	1:58 P.M.—4:52 P.M. 2/15/17	11	12	13	11	12	5	8	9
	K:B:BL = 36:31:14 = 1:86:39								
XII	4:52 P.M.—7:05 A.M. 2/16/17	10	5	6	5	7	7	9	6
	K:B:BL = 23:19:13 = 1:83:57								
XIII	7:05 A.M.—9:35 A.M. 2/16/17	46	40	36	31	18	33	22	7
	K:B:BL = 100:93:40 = 1:93:40								
XIV	1:26 P.M.—3:50 P.M. 2/16/17	17	20	16	19	15	14	11	12
	K:B:BL = 48:50:26 = 1:1.04:54								

* BL = Bordeaux mixture with excess of lime.

TABLE II (Continued)
(Series B.—Potted potatoes)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1K'	2B'	3K'	4B'	5K'	6BL'	7B'	8BL'
XV	5:32 P.M.—7:10 A.M. 2/17/17	3	14	6	18	6	27	19	23
	K':B':BL' = 15:51:50 = 1:3.4:3.3								
XVI	7:10 A.M.—1:20 P.M. 2/17/17	64	52	40	53	47	32	32	45
	K':B':BL' = 151:137:77 = 1:97:51 Sunshine								
XVII	2:08 P.M.—7:57 P.M. 2/17/17	24	20	17	22	21	16	15	18
	K':B':BL' = 72:57:34 = 1:79:47 Sunshine during early P. M. hours								
XVIII	7:57 P.M.—8:26 A.M. 2/18/17	2	10	9	10	6	10	10	10
	K':B':BL' = 17:30:20 = 1:1.76:1.18								
XIX	8:26 A.M.—4:39 P.M. 2/18/17	29	27	19	23	13	14	15	18
	K':B':BL' = 61:66:32 = 1:1.08:52 Cloudy								
XX	7:10 A.M.—3:42 P.M. 2/19/17	31	56	61	52	35	47	29	34
	K':B':BL' = 127:137:81 = 1:1.08:64 Sunshine								

standardization, each interval extending throughout the night or somewhat longer. We then find that the ratio has changed from 1.16 to 2.71, or an increase of 133 per cent as a result of the surface film. During the second interval after standardization, VI, a day interval, the transpiration loss under conditions of continuous sunshine is very little more than during a similar interval, II, before standardization. Interval III before standardization is scarcely comparable with interval VII after standardization, but it is interesting to note that the increased water loss due to Bordeaux has now apparently disappeared, and the loss from these plants exhibits a ratio lower than in the control. Moreover, there is no interval after standardization which compares with the dull cloudy interval before standardization.

In table II considerable individual variation is exhibited, so that the relation of the K, B, and BL plants is not as constant as might be desired in the intervals before standardization. There seems to be a tendency for the K and BL loss to show a fair constancy, whereas the B plants frequently show a relatively high ratio during the day intervals and a

lower ratio during the night intervals. Since the conditions are the same for all the plants, this variation is unexplained. Leaving individual variation out of consideration, it will be seen that for the whole period of the observations the water loss is again higher for the plants sprayed with Bordeaux and lime Bordeaux than for the control. More interesting, however, are certain comparisons between single intervals before and after standardization. Assuming that the plants in the different lots before and after standardization are more nearly comparable in intervals which are relatively close together, we may compare the first interval after spraying, XV, which in other cases has shown marked increase as a result of the Bordeaux application, with interval XII before standardization, these two being night intervals of approximately equal length. Again, we find that the effect of the Bordeaux film during the first interval after spraying is very considerable, giving a percentage increase of 310, and that the Bordeaux lime preparation shows an increase of 479 per cent. On the other hand, if we compare the second interval after spraying under conditions of sunshine, XVI, with the last interval before spraying, XIV, we find a slightly diminished transpiration in the sprayed plants. The ratios of all subsequent intervals except one after spraying, XVII-XX, are nearly constant and approach the normal or average before standardization,—the exception being interval XVIII. The exceptional interval is a night period where again the ratio for sprayed plants is high. It seems well here to emphasize the fact that environmental conditions are obviously in some way important in determining the increased transpiration due to surface films.

The data given for series C in table III is noteworthy for several reasons. In the first place, it will be seen that in the several intervals of standardization the L group of plants exhibits a relative falling off in the rate of transpiration. There was no apparent cause for this, as the soil conditions were as moist as in the other pots, and evidence of flagging was entirely lacking. In the second place, after spraying the water loss of the B' and BC' plants is very great during interval

IV, this interval being largely a night period. During the next interval (a day period), with conditions bright and warm, there is practically a return to the normal or standardization rate for the B' and BC' plants as compared with

TABLE III
(Series C.—Potted tomatoes)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1K	2B	3BC*	4L†	5BC	6B	7K	8L
I	3:50 P.M.—9:10 A.M. 1/12/17	26	23	27	27	31	33	34	36
	K:B:BC:L = 60:56:58:63 = 1:.93:.97:1.05 Sunshine P.M.; cloudy A.M.								
II	9:10 A.M.—12:37 P.M. 1/12/17	28	29	25	20	29	33	29	29
	K:B:BC:L = 57:62:54:49 = 1:1.09:.95:.86 Sunshine, some clouds								
III	12:37 P.M.—3:44 P.M. 1/12/17	24	30	23	13	27	28	20	15
	K:B:BC:L = 44:58:50:28 = 1:1.33:1.14:.45 Sunshine, some clouds								
		1K'	2B'	3BC'	4L'	5BC'	6B'	7K'	8L'
IV	5:22 P.M.—9:13 A.M. 1/13/17	22	84	75	29	84	92	26	37
	K':B':BC':L' = 48:176:159:66 = 1:3.67:3.31:1.38 Sunshine A.M.								
V	9:13 A.M.—1:46 P.M. 1/13/17	41	45	40	32	38	31	40	29
	K':B':BC':L' = 81:76:78:61 = 1:.94:.96:.75 Sunshine, temperature high								
VI	3:37 P.M.—10:10 A.M. 1/14/17	32	61	55	33	57	59	37	34
	K':B':BC':L' = 69:120:112:67 = 1:1.74:1.62:.97 Sunshine, temperature high								
VII	10:10 A.M.—1:38 P.M. 1/14/17	29	34	23	21	20	16	25	28
	K':B':BC':L' = 54:50:43:49 = 1:.93:.80:.91 Sunshine, temperature high								
VIII	1:38 P.M.—5:09 P.M. 1/14/17	15	16	11	13	12	13	12	---
	K':B':BC':L' = 27:29:23:(29 est.) = 1:1.07:.85:1.07 Sunshine, temp. high								
IX	5:09 P.M.—10:08 A.M. 1/15/17	16	52	45	28	30	35	18	---
	K':B':BC':L' = 34:87:75:(60 est.) = 1:2.56:2.21:1.76 Cloudy A.M.								

* BC = Bordeaux with excess of the copper salt. † L = lime wash.

the control. Interval VI, again largely a twilight and night period, shows a rise in the rate in favor of the B' and BC' sprayed plants, followed again by day intervals in which the normal is approached. It was this series in particular, which was conducted prior to series B, which suggested so definitely the importance of conditions in modifying the amount of the transpiration quantities after spraying. In the preceding

discussion of ratios mention has not been made of the L lot of plants, but owing to the successive falling off in their rate of water loss during the standardization interval, it was felt that this lot could not be considered entirely normal. Never-

TABLE IV
(Series D.—Potted tomatoes)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1B	2Fe*	3B	4Fe	5Al†	6Mg‡	7Al	8Mg
I	8:31 A.M.–3:42 P.M. 1/19/17	21	29	20	18	36	26	27	28
	B:Fe:Al:Mg = 41:47:63:54 = 1:1.15:1.54:1.32	Sunshine							
II	3:42 P.M.–9:35 A.M. 1/20/17	11	12	11	7	12	13	11	13
	B:Fe:Al:Mg = 22:19:23:26 = 1:.86:1.05:1.18	Sunshine							
III	9:35 A.M.–11:17 A.M. 1/20/17	6	9	6	8	11	7	7	10
	B:Fe:Al:Mg = 12:17:18:17 = 1:1.42:1.5:1.42	Sunshine							
		1B'	2Fe'	3B'	4Fe'	5Al'	6Mg'	7Al'	8Mg
IV	1:50 P.M.–10:12 P.M. 1/20/17	16	17	16	15	25	35	22	34
	B':Fe':Al':Mg' = 32:32:47:69 = 1:1:1.47:2.16	Cloudy							
V	10:12 P.M.–12:45 P.M. 1/21/17	25	33	22	21	28	38	33	38
	B':Fe':Al':Mg' = 47:54:61:76 = 1:1.15:1.3:1.62	Intermittent sunshine							
VI	10:48 P.M.–9:24 A.M. 1/22/17	16	19	11	12	15	17	17	20
	B':Fe':Al':Mg' = 27:31:32:37 = 1:1.15:1.19:1.37								
VII	9:24 A.M.–3:15 P.M. 1/22/17	23	21	21	17	12	15	18	22
	B':Fe':Al':Mg' = 44:38:30:37 = 1:.86:.68:.84								

* Fe = film of ferric hydrate. † Al = film of aluminum hydrate. ‡ Mg = film of magnesium hydrate.

theless, it exhibits on the whole much the same change of ratio with change of conditions as the B' and BC' lots. Here again, as in our earlier experiments, the effect of the lime film has not generally been to increase the transpiration loss to the same extent as the copper films.

The data for series D are introduced with some hesitation, owing to the fact that at the close of the experiment all of the plants except one of those sprayed with Bordeaux mixture showed some injury, the extent of this being the wilting or death of from 1 to 4 leaves of each plant. Nevertheless,

some suggestions are evident as a result of this work. As compared with Bordeaux mixture, the films of iron, aluminum, and magnesium hydrate exhibit in the earlier intervals after standardization a rate which is on the whole equal to or greater than that of the Bordeaux-sprayed plants. In the last interval, however, there is a distinct falling off in all of

TABLE V
(Series E.—Potted tomatoes)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1B	2B	3RB*	4RB	5K	6K	7RB	8K
I	1:12 P.M.—4:49 P.M. 2/23/17	36	45	41	49	40	48	44	51
	K:B:RB = 139:81:134 = 1:58:96	Sunshine, becoming cloudy							
II	4:49 P.M.—7:00 A.M. 2/24/17	33	55	30	34	38	34	38	40
	K:B:RB = 112:88:102 = 1:79:91	Hazy at 7 A.M.							
III	7:00 A.M.—2:55 P.M. 2/24/17	93	73	77	66	63	86	117	91
	K:B:RB = 240:166:260 = 1:69:108	Intermittent sunshine							
IV	3:25 P.M.—5:38 P.M. 2/24/17	5	2	4	3	3	2	5	4
	K:B:RB = 9:7:12 = 1:78:133	Hazy							
V	5:38 P.M.—8:09 A.M. 2/25/17	29	28	28	25	25	32	35	31
	K:B:RB = 88:57:88 = 1:65:1	Very hazy late P.M.							
		1B'	2B'	3RB'	4RB'	5K'	6K'	7RB'	8K'
VI	11:09 A.M.—5:36 P.M. 2/25/17	109	83	95	81	46	133	112	134
	K':B':RB' = 313:192:288 = 1:61:92	Sunshine							
VII	5:36 P.M.—7:14 A.M. 2/26/17	11	6	7	7	4	8	10	4
	K':B':RB' = 16:17:24 = 1:1.06:1.50								
VIII	7:14 A.M.—1:00 P.M. 2/26/17	49	29	32	34	18	55	47	45
	K':B':RB' = 118:75:113 = 1:64:96	Sunshine							
IX	1:26 P.M.—4:22 P.M. 2/26/17	24	19	16	14	21	29	22	29
	K':B':RB' = 79:43:52 = 1:54:66	Dull, becoming cloudy							
X	4:22 P.M.—7:10 A.M. 2/27/17	34	27	32	32	14	25	46	22
	K':B':RB' = 61:61:110 = 1:1:1.80	Cloudy							
XI	7:44 A.M.—4:07 P.M. 2/27/17	44	35	29	32	45	61	35	58
	K':B':RB' = 164:79:96 = 1:48:52	Cloudy							
XII	4:07 P.M.—7:11 A.M. 2/28/17	42	33	37	35	29	29	53	34
	K':B':RB' = 92:75:125 = 1:82:136								

* RB = red Bordeaux (erythrosin added).

the other lots as compared with the Bordeaux. It may perhaps be taken to suggest that the increased rate of transpiration of such films may in a measure be related to incipient injury, the rate being relatively high until this injury leads to wilting or death of a certain proportion of the leaves.

Series E was arranged with relatively old, potted tomato plants which had been cut back and had grown considerably "bunched." The greenhouse was maintained under the usual

TABLE VI
(Series F.—Potted marguerites)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1B	2R*	3B	4K	5R	6B	7K	8R
I	4:50 P.M.—9:25 A.M. 1/24/17	33	36	22	35	18	38	19	35
	K:B:R = 54:93:89 = 1:1.72:1.65								
II	10:10 A.M.—4 P.M. 1/24/17	124	129	121	147	57	135	75	158
	K:B:R = 222:380:344 = 1:1.71:1.55								
		1B'	2R'	3B'	4K'	5R'	6B'	7K'	8R'
III	4:47 P.M.—9:08 A.M. 1/25/17	15	24	17	12	23	27	14	18
	K':B':R' = 26:59:65 = 1:2.27:2.5								
IV	10:18 A.M.—3:03 P.M. 1/26/17	61	75	54	60	72	72	86	67
	K':B':R' = 146:187:214 = 1:1.28:1.47								

* R = resin Bordeaux.

conditions during intervals I-III and VIII-XII. During intervals IV-VII the walls and floors of the house were drenched morning and evening, and a small stream of water kept flowing through the house in an effort to maintain higher humidities. This was fairly successful except in interval VI, when the bright sunshine and high temperature made it difficult of accomplishment. During interval IV, moreover, the transpiration quantities are so small that the ratios are of questionable value. In this series three plants were treated with a reddened Bordeaux mixture, this being made by the addition of erythrosin to the usual Bordeaux until a deep red color was produced. The treated plants were sprayed copiously; in fact, until the mixture streamed from the plants.

TABLE VII
(Series G.—Tobacco)

EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1B	2K	3B	4K	5B	6K	7B	8K
I	4:30 P.M.-5:32 P.M. 1/17/18	4	8	3	9	5	6	3	2
	K:B = 25:15 = 1:.60	Bright at 4:30							
II	5:32 P.M.-7:34 P.M. 1/17/18	6	10	10	2	4	8	3	2
	K:B = 22:23 = 1:1.05								
III	7:34 P.M.-10:34 P.M. 1/17/18	6	10	11	10	5	11	2	4
	K:B = 35:24 = 1:.69								
IV	10:34 P.M.-7:01 A.M. 1/18/18	15	26	21	29	15	32	11	10
	K:B = 97:62 = 1:.64								
V	7:34 A.M.-8:41 A.M. 1/18/18	2	5	3	7	2	6	2	3
	K:B = 21:9 = 1:.43	Sunshine by 8 A.M.							
VI	8:41 A.M.-9:41 A.M. 1/18/18	6	5	6	7	8	8	2	8
	K:B = 28:22 = 1:.79	Sunshine							
VII	9:41 A.M.-10:41 A.M. 1/18/18	11	12	9	11	11	11	8	8
	K:B = 42:39 = 1:.93	Sunshine							
VIII	10:41 A.M.-11:41 A.M. 1/18/18	12	16	15	17	22	15	15	15
	K:B = 63:64 = 1:1.02	Sunshine							
IX	11:41 A.M.-12:41 P.M. 1/18/18	13	18	12	19	15	14	7	15
	K:B = 66:47 = 1:.71	Sunshine							
X	12:41 P.M.-1:41 P.M. 1/18/18	11	18	13	16	15	17	10	12
	K:B = 63:49 = 1:.78	Sunshine							
XI	2:00 P.M.-3:00 P.M. 1/18/18	11	15	10	17	11	14	11	14
	K:B = 60:43 = 1:.72	Sunshine							

TABLE VII (Continued)

		1B'	2K'	3B'	4K'	5B'	6K'	7B'	8K'
XII	4:30 P.M.-5:30 P.M. 1/18/18	12	5	10	4	13	4	12	0
	K':B' = 13:47 = 1:3.62								
XIII	5:30 P.M.-7:32 P.M. 1/18/18	9	2	12	4	13	4	10	0
	K':B' = 10:44 = 1:4.4								
XIV	7:32 P.M.-10:32 P.M. 1/18/18	13	4	8	3	19	4	15	2½
	K':B' = 13.5:55 = 1:4.07								
XV	10:51 P.M.-7:15 A.M. 1/19/18	31	10	24	7	40	9	32	8
	K':B' = 34:127 = 1:3.74								
XVI	7:44 A.M.-8:44 A.M. 1/19/18	9	7	5	7	4	9	5	4
	K':B' = 27:23 = 1:85	Glass frosted during this interval							
XVII	8:44 A.M.-9:44 A.M. 1/19/18	9	8	7	10	10	8	9	6
	K':B' = 32:35 = 1:1.09	Sunshine							
XVIII	9:44 A.M.-10:44 A.M. 1/19/18	14	17	11	14	15	15	14	14
	K':B' = 60:54 = 1:90	Sunshine							
XIX	10:44 A.M.-11:45 A.M. 1/19/18	9	11	9	15	14	9	12	13
	K':B' = 48:44 = 1:92	Cloudy during most of interval							
XX	11:45 A.M.-12:45 P.M. 1/19/18	13	14	10	8	12	14	8	13
	K':B' = 49:43 = 1:88	Cloudy							
XXI	12:45 P.M.-1:49 P.M. 1/19/18	11	13	12	13	12	11	11	11
	K':B' = 48:46 = 1:96	Cloudy							
XXII	1:49 P.M.-2:50 P.M. 1/19/18	7	7	4	9	3	7	6	7
	K':B' = 30:20 = 1:67	Cloudy							
XXIII	2:50 P.M.-3:50 P.M. 1/19/18	7	4	2	2	9	5	6	2
	K':B' = 13:24 = 1:1.85	Cloudy							

liminary trial it was seen that the usual Bordeaux mixtures would not adhere well, so that in addition to this a resin Bordeaux was employed. All treated plants were sprayed heavily. The transpiration quantities were remarkably uniform in the standardization intervals, and after spraying the increased transpiration for the sprayed plants was considerable, the ratio for Bordeaux changing from 1:.71 to 1:2.27. The group treated with the resin Bordeaux gave somewhat greater transpiration loss during the same interval. Unfortunately, after this first interval, and with the higher temperature of the greenhouse during the day, injury began to

It seemed desirable to employ in one series some broad-leaved, fairly succulent plant, and at the same time to make several observations during the evening or night interval in order to control more completely the previous experiments, as a result of which the night intervals of sprayed plants had almost invariably shown the highest transpiration ratios. The results of series G are particularly interesting. It is felt, however, that the variability exhibited by the different groups of plants during, say, the first four to six intervals, indicates a lack of adjustment to the new conditions; and perhaps it would be best to regard the last five intervals of the standardization period (VII–XI) as expressing more nearly the true ratio of the two groups of plants.

The plants were sprayed moderately, and, as will be noted, three observations were made between 4:30 and 10:30 P. M. From the results noted in intervals XII–XIV there was, after

		1B	2K	3B	4K	5B	6K	7B	8K
I	10:00 A.M.-11:00 A.M. 10/25/17	18	18	----	15	21	12	18	11
	K:B = 56:57 = 1:1.02	Cloudy							
II	11:00 A.M.-12:04 A.M. 10/25/17	13	16	----	12	18	9	12	2
	K:B = 39:43 = 1:1.10	Cloudy							
III	12:04 A.M.-1:00 P.M. 10/25/17	16	19	----	15	18	12	19	10
	K:B = 56:53 = 1:1.95	Cloudy							
IV	1:00 P.M.-2:09 P.M. 10/25/17	12	13	----	13	17	17	5	1
	K:B = 44:34 = 1:1.77	Cloudy							
V	2:09 P.M.-3:08 P.M. 10/25/17	11	11	----	11	17	6	13	8
	K:B = 36:41 = 1:1.14	Cloudy							
VI	4:01 P.M.-7:15 A.M. 10/26/17	44	52	----	32	61	50	28	24
	K:B = 158:133 = 1:1.84	Cloudy							

TABLE IX
(Series J.—Castor bean leaves)
EFFECT OF BORDEAUX MIXTURE ON THE RATE OF TRANSPIRATION.
DATA IN GRAMS

		1K	2B	3K	4B	5K	6B	7K	8B
I	10:46 A.M.—11:18 A.M. 9/24/17	2.6	5.0	8.7	9.1	0.3	8.4	5.1	8.8
	K:B = 16.7:31.3 = 1:1.87	Sunshine							
II	11:18 A.M.—11:48 A.M. 9/24/17	7.1	6.9	13.4	8.0	1.0	12.2	6.5	11.8
	K:B = 28.0:38.9 = 1:1.35	Sunshine							
III	11:48 A.M.—12:18 P.M. 9/24/17	5.1	7.7	11.5	6.6	1.0	14.5	7.9	12.2
	K:B = 25.5:41.0 = 1:1.61	Sunshine							
IV	12:18 P.M.—12:49 P.M. 9/24/17	11.2	6.5	7.0	5.5	1.3	10.3	6.2	9.0
	K:B = 25.7:31.3 = 1:1.22	Sunshine							
V	12:49 P.M.—1:45 P.M. 9/24/17	6.4	14.3	7.5	8.9	1.1	22.1	15.7	18.1
	K:B = 30.7:63.4 = 1:2.07	Sunshine							
		1K'	2B'	3K'	4B'	5K'	6B'	7K'	8B'
VI	3:21 P.M.—3:55 P.M. 9/24/17	1.2	6.2	3.2	4.2	0.7	12.3	8.0	8.6
	K':B' = 13.1:31.3 = 1:2.39	Sunshine							
VII	3:55 P.M.—4:29 P.M. 9/24/17	1.3	6.1	3.5	4.0	1.0	9.1	4.2	6.6
	K':B' = 10.0:25.8 = 1:2.58	Sunshine							
VIII	4:29 P.M.—5:04 P.M. 9/24/17	0.3	4.0	1.4	2.9	0.8	6.9	3.6	5.7
	K':B' = 6.6:19.5 = 1:2.95	Sunshine							
IX	5:04 P.M.—7:06 P.M. 9/24/17	1.6	7.0	2.1	5.8	2.0	12.1	5.5	8.3
	K':B' = 11.2:33.2 = 1:2.96								
X	7:06 P.M.—9:08 P.M. 9/24/17	1.7	4.0	1.3	5.2	1.5	6.9	4.0	5.1
	K':B' = 8.5:21.2 = 1:2.49								
XI	9:08 P.M.—7:03 A.M. 9/25/17	3.3	4.5	1.6	5.4	2.2	8.5	4.1	6.6
	K':B' = 11.2:25.0 = 1:2.23								
XII	7:03 A.M.—9:10 A.M. 9/25/17	1.6	11.4	5.0	8.5	1.4	7.5	10.4	15.0
	K':B' = 18.4:42.4 = 1:2.34	Weak sunshine							
XIII	9:10 A.M.—10:14 A.M. 9/25/17	2.9	11.2	2.4	7.1	1.3	21.4	11.9	18.4
	K':B' = 18.5:58.1 = 1:3.14	Sunshine							
XIV	10:14 A.M.—11:09 A.M. 9/25/17	3.6	7.3	2.2	7.1	1.2	23.1	14.4	21.3
	K':B' = 21.4:58.8 = 1:2.75	Sunshine							

It had been intended to repeat the experiments with excised leaves under various environmental conditions, but the high temperature prevailing when the material was ready in the

early fall rendered this impossible. Leaves of the castor bean, which in our earlier work had been found favorable for studies of this kind, were procurable in large number, but under the conditions maintaining in the greenhouse they proved subject to great fluctuations and to severe wilting. In many cases the leaves wilted in test chambers where the atmosphere was kept fairly moist, and the indications were that the cause might lie in the movement of viscous materials into the conducting channels. Nevertheless, one completed series was maintained under satisfactory conditions and the results are shown in table ix. The leaf stems were inserted through one mouth of a Wolff bottle into a weak Crone solution, movement of the leaves with the rotation of the table, when this occurred, being prevented by means of a lump of plasticene. In this case, however, weighings were made on a trip balance, weighing accurately to .1 gram.

From the data presented it will be seen that the sprayed plants exhibit an increase in the transpiration loss throughout all intervals of the experiment. In this case the increased water loss in the night interval is no more pronounced than during any other interval. The results here are in complete accord with those previously reported from this laboratory, and it would seem reasonable to anticipate that some general explanation may be advanced to account for the striking differences noted in these experiments as between excised leaves, on the one hand, and potted plants, such as the potato, tomato, and tobacco, on the other.

DISCUSSION AND SUMMARY

The data presented in this paper offer a mass of additional proof to establish the point that a film of Bordeaux mixture or of certain other materials of similar physical characteristics influence, often to a marked degree, the rate of water loss from the plant. Although the work accomplished does not yet include as many types of plants as might be wished, nor are the conditions of the environment so completely measured or controlled that the relation of this increased water loss to environmental factors may be clearly defined, yet that both

plant type and summation of conditions are factors of importance seems a well-warranted conclusion, as will be developed below.

The results may be discussed in three categories, in respect to the plant material employed. In the first type of material the usual mesophytic potted plant has constituted the experimental object; in the second, a plant of xerophytic surface modifications, *Cyperus esculentus*; and third, abscised leaves of castor beans. Without exception, the potted plants in the first category furnished consistent evidence that under the conditions of our experiments increase in the rate of transpiration occurs mainly, if not entirely, during the night intervals. There may be little or no change in the rate of transpiration during the day intervals, and, to a considerable extent, at least, this is independent of slight changes in weather conditions,—some of the experiments having been conducted in bright sunshine, others in cloudy weather, and in still other cases different intervals in the same series have furnished varied conditions. Nevertheless, the fact that the night interval has invariably exhibited, in respect to the sprayed plants, a transpiration increase, makes it clear that in some way the sum of night and day conditions is responsible for the increased water loss. Attempts to increase or diminish the humidity in the greenhouse by flooding with water has not resulted in any indications which alone might explain the observed phenomenon.

The greenhouse was subject to a rise and fall of temperature from midnight to midday, amounting to from 7 to 15° C. It has repeatedly been noticed that under such greenhouse conditions seedlings exhibit the phenomenon of guttation to some degree, often to a very high degree. Now if it may be assumed that the potted plants experimented upon were subject each night to conditions inducing guttation, or at least incipient guttation, this condition might be made use of to explain the phenomenon in the following way: A film of Bordeaux mixture on the surface of a plant in a state of guttation would probably act more or less as a bibulous surface, taking water directly from the interior of the plant, through

at least some continuous water channels established by means of the open water-suffused stomata. Under such conditions it seems fair to assume that the water would spread through the film of Bordeaux mixture, and the evaporating surface would thereby be greatly increased. On the other hand, during the day, as this state of incipient guttation might give way to a condition in which the interchange between the inner and outer atmosphere is governed wholly by the diffusion of water vapor, the presence of an absorbent surface film would have little, or at least far less, power to increase the evaporating surface, or in any other known manner to facilitate evaporation.

Again, taking the case of *Cyperus*, an explanation of the failure of the surface film to increase the transpiration rate might then be found both in the fact that the stomatal openings are exceedingly small, and that the air space of the leaf tissue is very limited in extent. In all probability, with such material, a state approaching guttation would be realized with great difficulty, if at all, and a "clogging" of the stomata might indeed tend to inhibit transpiration.

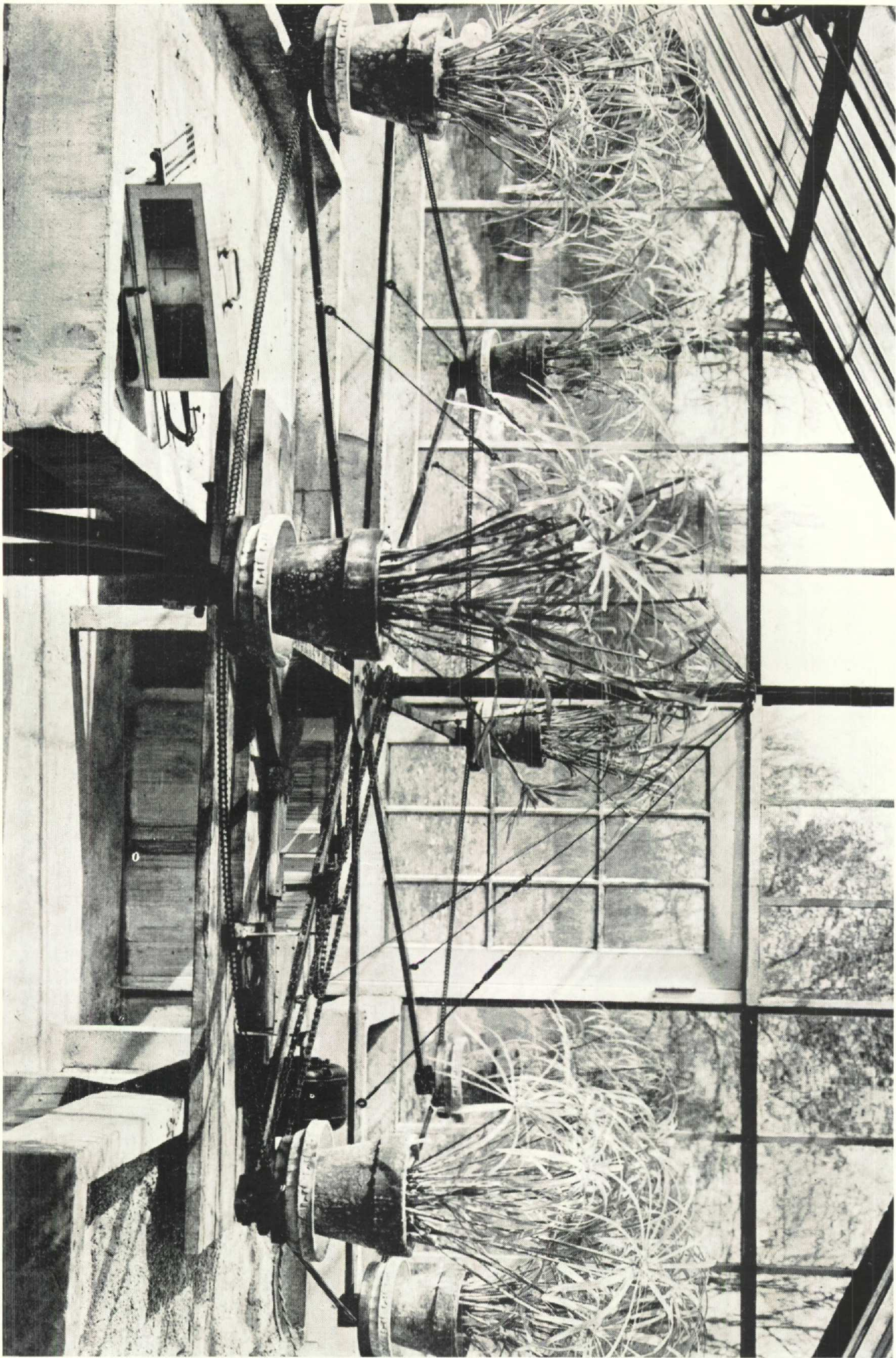
The excised leaves which are able to maintain themselves at all might be expected to exhibit very different water relations, and it is not possible from the data at hand to conclude that in this case there is in reality any possibility of a state of incipient guttation. This is, however, possible. At any rate, the writers have found no satisfactory explanation of the results obtained except the one just discussed. Some phases of this explanation are susceptible of direct experimentation and in further work it is proposed to subject the matter to critical test. For the present it is offered as a suggestion merely.

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EXPLANATION OF PLATE

PLATE 10

General view of rotating "table" arranged with *Cyperus*. The thermo-hygrograph employed—removed from sheltered stand—is also shown.



DUGGAR AND BONNS—RATE OF TRANSPIRATION

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No. 3

THE THELEPHORACEAE OF NORTH AMERICA. IX¹

ALEURODISCUS

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ALEURODISCUS

Aleurodiscus Rabenhorst, Fungi Eur. Exs., 1824 (without diagnosis). 1874; Hedwigia **13** : 184 (without diagnosis). 1874; Schroeter, Krypt.-Fl. Schlesien **3** : 429. 1888; Engl. & Prantl, Nat. Pflanzenfam. (1.1**) : 120. 1898; Patouillard, Essai Taxon. Hym. 52. 1900; v. Höhn. & Litsch. K. Akad. Wiss. Wien Sitzungsber. **116** : 793. *pl.* 1-4. 1907; Bourd. & Galz. Soc. Myc. Fr. Bul. **28** : 349. 1913.

Fructifications resupinate, sometimes with margin free all around and somewhat saucer-shaped, rarely dimidiate and attached by the base, drying coriaceous; hymenium pulverulent; paraphyses noteworthy, modified into forms such as moniliform, or racemose by presence of short lateral branches—these paraphyses are sometimes called dendrophyses; granular or crystalline matter often in great quantity between the basidia, paraphyses, and hyphae of the fructification; basidia simple, usually large and with four large sterigmata; spores simple, usually large, with colorless cell wall.

The type species is *Aleurodiscus amorphus* (Pers.) Rabenh. originally published as *Peziza amorpha* by Persoon, then transferred to *Thelephora* by Fries when known to be a basid-

¹ Issued September 20, 1918.

iomycete, and finally referred by Fries with doubt to *Corticium* and regarded by Quelet as a *Cyphella*.

Into *Aleurodiscus* have been assembled species of related structure which were originally published in *Corticium* and *Stereum* on the basis of form of fructification, but which are noteworthy by basidia and spores often enormous in dimensions for the genera to which these species were originally referred, and which sometimes have paraphyses of remarkable form, and the fructification greatly thickened in some species by so large an amount of incrustated or granular matter as to render it very difficult to make out the detailed structure of basidia and paraphyses in good sectional preparations. The granular and crystalline matter may be dissolved from the sections by warming them on the slide in a few drops of dilute hydrochloric acid, but with the disadvantage of leaving the paraphyses and other organs with rather vague outlines, as though somewhat collapsed or disorganized.

Some species now referred to *Aleurodiscus* are intermediate between this genus and other genera by the absence of any notable development of some one or other of the foregoing characters, and it is too largely a matter of personal opinion as to just which species should be transferred. On the whole, *Aleurodiscus* is probably useful, although bound to be a source of confusion by introducing into a scheme of classification based upon form and general structure of fructification a conflicting scheme of classification based upon rather trivial, and often poorly shown, features of microscopic detail, with disregard of diversity in form and general structure of fructification involved. Innovations of this kind should certainly be exceptional.

Of the 25 species of *Aleurodiscus* which have been recognized up to the present time, 14 occur in North America, 8 in Europe, 5 in Asia and Australia, 2 in Africa, and 2 in South America. *A. acerinus* is the only one of these which is of world-wide distribution; *A. amorphus* is the only other species common to both Europe and North America, and in North America it is restricted to northern United States and Canada. Only 3 species, *A. acerinus*, *A. candidus*,